What is claimed is:

1. An optical apparatus comprising:

a microscope optical system having:

a light source,

an illumination optical system for leading light emitted from said light source to an object to be observed,

an imaging optical system for forming an image of said object, and

at least one polarizing member for separating the light from said light source into two polarized components;

an adjusting member for changing an amount of retardation between said two polarized components; and

an image pick-up member for photographing a differential interference contrast image of said object;

operated through a process for photographing two differential interference contrast images relative to said object in which amounts of retardation are equal, but have different signs,

wherein a processing unit is provided and is operated through a calculation process for performing a differential calculation and a summed calculation relative to respective pixels corresponding to said two differential interference contrast images to obtain differential image information and summed image information and a calculation process for detecting an amount of phase on a surface of said object by using one of the following equations:

$$\Phi (x, y) = k \cdot \{(1 - \cos \theta) \cdot d (x, y) / \alpha\} / \{\sin \theta \cdot [1 - \{d (x, y) / \alpha\}^2 / 2]\}$$

$$\Phi (x, y) = k \cdot \tan^{-1} [\{(1 - \cos \theta) \cdot d (x, y) / \alpha\}$$

$$/ \{\sin\theta \cdot [1 - \{d(x, y) / \alpha\}^2 / 2]\}]$$

where θ is the amount of retardation; $\Phi(x, y)$ is said amount of phase on the surface of said object corresponding to said differential image information and said summed image information; when said differential image information is represented by $D(x, y)$, $d(x, y)$ is image information in which said differential image information $D(x, y)$ is deconvoluted by using an optical transfer function of said microscope optical system; when said summed image information is represented by $S(x, y)$, α is an average value of said summed image information $S(x, y)$; and $k = \lambda/4\pi$, where λ is a wavelength.

2. An optical apparatus comprising:

an interference optical system having:

a light source,

an illumination optical path for leading light emitted from said light source to an object to be observed, and

a reference optical path for leading the light from said light source to a reference surface; and

an image pick-up member for photographing an interference image of said object formed by said interference optical system;

wherein a processing unit is provided and is operated through a calculation process for detecting an amount of phase on a surface of said object by using one of the following equations:

$$\Phi(x, y) = k \cdot \{h(x, y) / Jm(x, y)\} / \{[1 - \{h(x, y) / Jm(x, y)\}^2 / 2]\}$$

$$\Phi(x, y) = k \cdot \tan^{-1} [k \cdot \{h(x, y) / Jm(x, y)\} / \{[1 - \{h(x, y) / Jm(x, y)\}^2 / 2]\}]$$

where when image information in which a phase distribution of said object is pictur-

ized is represented by H (x, y), h (x, y) is image information in which said image information H (x, y) is deconvoluted by using an optical transfer function of said interference optical system; when image information in which an intensity distribution is picturized is represented by J (x, y), Jm (x, y) is image information in which maxima of said image information J (x, y) are enveloped; Φ (x, y) is said amount of phase on the surface of said object; and $k = \lambda/4\pi$, where λ is a wavelength.

3. An optical apparatus comprising:

a microscope optical system having:

a light source,

an illumination optical system for leading light emitted from said light source to an object to be observed,

an imaging optical system for forming an image of said object, and

at least one polarizing member for separating the light from said light source into two polarized components;

an adjusting member for changing an amount of retardation between said two polarized components; and

an image pick-up member for photographing a differential interference contrast image of said object;

operated through a process for photographing two differential interference contrast images relative to said object in which amounts of retardation are equal, but have different signs,

wherein a processing unit is provided and is operated through a calculation process for performing a differential calculation and a summed calculation relative to respective pixels corresponding to said two differential interference contrast images to obtain differential image information and summed image information and a calculation

process for detecting an amount of phase on a surface of said object by using one of the following equations:

$$\Phi(x, y) = k \cdot \{(1 - \cos\theta) \cdot d(x, y) / \beta(x, y)\} / \{\sin\theta \cdot [1 - \{d(x, y) / \beta(x, y)\}^2 / 2]\}$$

$$\Phi(x, y) = k \cdot \tan^{-1} [\{(1 - \cos\theta) \cdot d(x, y) / \beta(x, y)\} / \{\sin\theta \cdot [1 - \{d(x, y) / \beta(x, y)\}^2 / 2]\}]$$

where θ is the amount of retardation; $\Phi(x, y)$ is said amount of phase on the surface of said object corresponding to said differential image information and said summed image information; when said differential image information is represented by $D(x, y)$, $d(x, y)$ is image information in which said differential image information $D(x, y)$ is deconvoluted by using an optical transfer function of said microscope optical system; when said summed image information is represented by $S(x, y)$, $\beta(x, y)$ is image information enveloping maxima of said summed image information $S(x, y)$; and $k = \lambda/4\pi$, where λ is a wavelength.

4. An optical apparatus comprising:

a microscope optical system having:

a light source,

an illumination optical system for leading light emitted from said light source to an object to be observed,

an imaging optical system for forming an image of said object, and

at least one polarizing member for separating the light from said light source into two polarized components;

an adjusting member for changing an amount of retardation between said two polarized components; and

an image pick-up member for photographing a differential interference contrast

image of said object;

operated through a process for photographing two differential interference contrast images relative to said object in which amounts of retardation are equal, but have different signs,

wherein a processing unit is provided and is operated through a calculation process for performing a differential calculation and a summed calculation relative to respective pixels corresponding to said two differential interference contrast images to obtain differential image information and summed image information and a calculation process for detecting an amount of phase on a surface of said object by using one of the following equations:

$$\Phi(x, y) = k \cdot \{(1 - \cos\theta) \cdot d(x, y)\} / \{\sin\theta \cdot \Gamma(x, y)\}$$

$$\Phi(x, y) = k \cdot \tan^{-1}[k \cdot \{(1 - \cos\theta) \cdot d(x, y)\} / \{\sin\theta \cdot \Gamma(x, y)\}]$$

Where θ is the amount of retardation; $\Phi(x, y)$ is said amount of phase on the surface of said object corresponding to said differential image information and said summed image information; when said differential image information is represented by $D(x, y)$, $d(x, y)$ is image information in which said differential image information $D(x, y)$ is deconvoluted by using an optical transfer function of said microscope optical system; when said summed image information is represented by $S(x, y)$, $\Gamma(x, y)$ is image information in which information of a low-frequency component is extracted from said summed image information $S(x, y)$; and $k = \lambda/4\pi$, where λ is a wavelength.

5. An optical apparatus comprising:

an interference optical system having:

a light source,

an illumination optical path for leading light emitted from said light source to an object to be observed, and

a reference optical path for leading the light from said light source to a reference surface; and

an image pick-up member for photographing an interference image of said object formed by said interference optical system;

wherein a processing unit is provided and is operated through a calculation process for detecting an amount of phase on a surface of said object by using one of the following equations:

$$\Phi (x, y) = k \cdot \{h (x, y) / Jc\} / \{[1 - \{h (x, y) / Jc\}^2 / 2]\}$$

$$\Phi (x, y) = k \cdot \tan^{-1} [k \cdot \{h (x, y) / Jc\} / \{[1 - \{h (x, y) / Jc\}^2 / 2]\}]$$

where when image information in which a phase distribution of said object is picturized is represented by H (x, y), h (x, y) is image information in which said image information H (x, y) is deconvoluted by using an optical transfer function of said interference optical system; when image information in which an intensity distribution is picturized is represented by J (x, y), Jc is a value in which maxima of said image information J (x, y) are averaged; Φ (x, y) is the amount of phase on the surface of said object; and $k = \lambda/4\pi$, where λ is a wavelength.

6. An optical apparatus comprising:

an interference optical system having:

a light source,

an illumination optical path for leading light emitted from said light source to an object to be observe, and

a reference optical path for leading the light from said light source to a reference surface; and

an image pick-up member for photographing an interference image of said object formed by said interference optical system;

wherein a processing unit is provided and is operated through a calculation process for detecting an amount of phase on a surface of said object by using one of the following equations:

$$\Phi(x, y) = k \cdot \{h(x, y) / Ja(x, y)\} / \{[1 - \{h(x, y) / Ja(x, y)\}^2 / 2]\}$$

$$\Phi(x, y) = k \cdot \tan^{-1} [k \cdot \{h(x, y) / Ja(x, y)\} / \{[1 - \{h(x, y) / Ja(x, y)\}^2 / 2]\}]$$

where when image information in which a phase distribution of said object is picturized is represented by H (x, y), h (x, y) is image information in which said image information H (x, y) is deconvoluted by using an optical transfer function of said interference optical system; when image information in which an intensity distribution is picturized is represented by J (x, y), Ja (x, y) is a value in which said image information J (x, y) is divided as a predetermined region and which is averaged in said region; Φ (x, y) is the amount of phase on the surface of said object; and $k = \lambda/4\pi$, where λ is a wavelength.

7. An optical apparatus comprising:

an interference optical system having:

a light source,

an illumination optical path for leading light emitted from said light source to an object to be observe, and

a reference optical path for leading the light from said light source to a reference surface; and

an image pick-up member for photographing an interference image of said object formed by said interference optical system;

wherein a processing unit is provided and is operated through a calculation process for

detecting an amount of phase on a surface of said object by using one of the following equations:

$$\Phi (x, y) = k \cdot \{h (x, y) / JL (x, y)\} / \{[1 - \{h (x, y) / JL (x, y)\}^2 / 2]\}$$

$$\Phi (x, y) = k \cdot \tan^{-1} [k \cdot \{h (x, y) / JL (x, y)\} / \{[1 - \{h (x, y) / JL (x, y)\}^2 / 2]\}]$$

where when image information in which a phase distribution of said object is picturized is represented by H (x, y), h (x, y) is image information in which said image information H (x, y) is deconvoluted by using an optical transfer function of said interference optical system; when image information in which an intensity distribution is picturized is represented by J (x, y), JL (x, y) is image information in which a low-frequency component is extracted from said image information J (x, y); Φ (x, y) is the amount of phase on the surface of said object; and $k = \lambda/4\pi$, where λ is a wavelength.

8. An optical apparatus comprising:

a microscope optical system having:

a light source,

an illumination optical system for leading light emitted from said light source to an object to be observed,

an imaging optical system for forming an image of said object, and

at least one polarizing member for separating the light from said light source into two polarized components;

an adjusting member for changing an amount of retardation between said two polarized components; and

an image pick-up member for photographing a differential interference contrast image of said object;

operated through a process for photographing two differential interference contrast images relative to said object in which amounts of retardation are equal, but have different signs,

wherein said optical apparatus is operated through a process for performing a differential calculation and a summed calculation relative to respective pixels corresponding to said two differential interference contrast images to obtain differential image information and summed image information and a process for calculating a phase distribution from said differential image information and said summed image information, having a processing unit operated through a calculation process for detecting a phase distribution on said object by using the following equation:

$$\Phi (x, y) = \varphi (x, y) / \{1 - [\varphi (x, y)]^2 / 2\}$$

where $\varphi (x, y)$ is a phase distribution calculated from said differential image information and said summed image information and $\Phi (x, y)$ is a phase distribution on said object.

9. An optical apparatus comprising:

a microscope optical system having:

a light source,

an illumination optical system for leading light emitted from said light source to an object to be observed,

an imaging optical system for forming an image of said object, and

at least one polarizing member for separating the light from said light source into two polarized components;

an adjusting member for changing an amount of retardation between said two polarized components; and

an image pick-up member for photographing a differential interference contrast

image of said object;

operated through a process for photographing two differential interference contrast images relative to said object in which amounts of retardation are equal, but have different signs,

wherein said optical apparatus is operated through a process for performing a differential calculation and a summed calculation relative to respective pixels corresponding to said two differential interference contrast images to obtain differential image information and summed image information, a process for using an optical transfer function of said imaging optical system for deconvolution processing of said differential image information, and a process for calculating a phase distribution from said differential image information obtained by the deconvolution processing and said summed image information, having a processing unit operated through a calculation process for detecting a phase distribution on said object by using the following equation:

$$\Phi (x, y) = \varphi_d (x, y) / \{1 - [\varphi_d (x, y)]^2 / 2\}$$

where $\varphi_d (x, y)$ is a phase distribution calculated from said differential image information obtained by the deconvolution processing and said summed image information and $\Phi (x, y)$ is a phase distribution on said object.

10. An optical apparatus comprising:

a microscope optical system having:

a light source,

an illumination optical system for leading light emitted from said light source to an object to be observed,

an imaging optical system for forming an image of said object, and

at least one polarizing member for separating the light from said light source

into two polarized components;

an adjusting member for changing an amount of retardation between said two polarized components; and

an image pick-up member for photographing a differential interference contrast image of said object;

operated through a process for photographing at least three differential interference contrast images of different amounts of retardation,

wherein said optical apparatus is operated through a process for calculating a phase distribution from said at least three differential interference contrast images of different amounts of retardation, having a processing unit operated through a calculation process for detecting a phase distribution on said object by using the following equation:

$$\Phi(x, y) = \varphi_f(x, y) / \{1 - [\varphi_f(x, y)]^2 / 2\}$$

where $\varphi_f(x, y)$ is a phase distribution calculated from said three differential interference contrast images and $\Phi(x, y)$ is a phase distribution on said object.

11. An optical apparatus comprising:

a microscope optical system having:

a light source,

an illumination optical system for leading light emitted from said light source into an object to be observed,

an imaging optical system for forming an image of said object, and

at least one polarizing member for separating the light from said light source into two polarized components;

an adjusting member for changing an amount of retardation between said two polarized components; and

an image pick-up member for photographing a differential interference contrast image of said object;

operated through a process for photographing at least three differential interference contrast images of different amounts of retardation,

wherein said optical apparatus is operated through a process for calculating a phase distribution from said at least three differential interference contrast images of different amounts of retardation and a process for using an optical transfer function of said imaging optical system for deconvolution processing of a calculated phase distribution, having a processing unit operated through a calculation process for detecting a phase distribution on said object by using the following equation:

$$\Phi(x, y) = \varphi_{fd}(x, y) / \{1 - [\varphi_{fd}(x, y)]^2 / 2\}$$

where $\varphi_{fd}(x, y)$ is a phase distribution obtained by the deconvolution processing and $\Phi(x, y)$ is a phase distribution on said object.

12. An optical apparatus comprising:

an interference optical system having:

a light source;

an illumination optical path for leading light emitted from said light source into an object to be observed; and

a reference optical path for leading the light from said light source to a reference surface; and

an image pick-up member for photographing an interference image of said object formed by said interference optical system;

wherein said optical apparatus is operated through a process for calculating a phase distribution from a photographed interference image and a calculation process for detecting a phase distribution on said object by using the following equation:

$$\Phi(x, y) = \varphi_i(x, y) / \{1 - [\varphi_i(x, y)]^2 / 2\}$$

where $\varphi_i(x, y)$ is a phase distribution calculated from said photographed interference image and $\Phi(x, y)$ is a phase distribution on said object.